Decision-Making Process for Buffer Dimensioning in Manufacturing

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Abstract. Systematic and stochastic variations, both endogenous and exogenous to companies, are a constant challenge for decision makers struggling to maintain a competitive advantage for the business. In response the decision maker introduces buffers to absorb variations but this does not target the source of the problem. The first step should instead be to focus on how to reduce variations and then to handle the remnant variations. In summary the first step should be to perform variation management and then as the second step buffer management should be applied. The combination of these two subprocesses represent service performance management and within this context is buffer dimensioning a key challenge. Input data, decision maker and process logic are identified as three key aspects of buffer dimensioning which are integrated and resulting in six scenarios. These scenarios unravel different conditions for performing buffer dimensioning and facilitate an awareness of a match or mismatch between current and desired situation.

Keywords: Buffer dimensioning · Dimensioning process · Service performance management

1 Introduction

Competitiveness can be based on different business characteristics such as patents protecting a market, a unique brand that attracts customers or a value-adding flow aligned with customer requirements. From a manufacturing perspective the flow-based type of competitiveness is of particular interest since this is where manufacturing is active in providing the foundation of competitiveness. A swift and even flow is in line with the one-piece continuous flow portrayed as the ideal state, according to lean thinking. This state is however seldom reached except for in isolated segments of the flow. Instead, a holistic picture of the flow unravels a number of discontinuities that represent variations in different shapes. Such variations may occur along the flow in terms of e.g. different lot sizes or capacity availability but can also be exogenous and related to characteristics of demand or external supply. Even though there are a wide set of variations, both systematic and stochastic, they have in common that they represent major challenges to decision making. Frequently the countermeasure to variations is to introduce buffers. This approach does however overlook the potential in first addressing and reducing the variations, and as a consequence also reduces the need for buffers. The challenge is that there are numerous sources of variations affecting a business. In other

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words, it is not enough to only consider one type of variation, it is important to manage all variations that have significant impact on the delivery capability, and hence the competitiveness. Previous studies have even showed that variance reducing activities have a greater impact on the output rate than a buffer such as safety stock [1]. However, it is most often neither economically sustainable nor viable trying to eliminate all variations. Variation management (VM) with the intention to reduce variations is therefore recommended as a first step before addressing variations by the use of buffers. The total amount of variations sets the preconditions for the need of buffers, realized in terms of safety stocks, safety capacity or safety lead-time, that can be used to absorb variations and protect the delivery capability.

To actually manage buffers is referred to as Buffer management (BM), which complements VM, and concerns decisions regarding the selection, positioning and dimensioning of buffers. In the current body of knowledge, studies have showed that an additional amount of resources can, for example, reduce lead-times [2] and increase responsiveness [3]. BM should therefore not be confused with reducing variations through VM. BM is rather a response to this and an approach to absorb variations [4]. This is an important notion since buffers will not reduce the causes that create challenges through variations, rather it is a symptomatic treatment to decrease the effects of variations. In order to minimize the effects of variations, by utilizing buffers, it is of outmost importance that the right buffer and buffer size is configured. Given that decisions are made for the type of buffer and position, the decision of buffer size remains. Buffer dimensioning refers to the process of the latter concern, focusing on determining the right buffer size based on the requirements by utilizing different dimensioning methods. For materials the literature is vast with for example different methods to calculate an appropriate safety stock level for certain circumstances and trade-offs between different cost components. However, for safety capacity and safety lead-time the theoretical support is not as prominent. This is also observed in industrial practice where managers have expressed a lack of decision support for dimensioning in general, independent of the type of buffer [5]. The purpose of this research is therefore to outline the key aspects of buffer management, with focus on the implications for the decision-making process for buffer dimensioning.

This research builds on insights from practitioners and is a conceptualization of findings from a research project. The remainder of this paper is structured as follows. First, a theoretical frame of reference is presented where VM and BM are briefly described. Thereafter an integrated process of VM and BM is discussed from a general perspective for the key aspects included in service performance management, followed by a detailed perspective for how buffer dimensioning varies depending on the context. Finally, the insights from this research are interpreted in terms of managerial implications by some concluding remarks.

2 Theoretical Frame of Reference

The process for establishing service performance is in focus here and it encompasses variations management and buffer management. This chapter is therefore dedicated to the parts that influence the service performance.

2.1 Variation Management

All companies are to some extent exposed to variations. Endogenous variations in processes have been the focus of attention in quality management literature due to the fact that variations exist in all sort of processes and that variations are sources to quality problems [6]. Exogenous variations as demand is, however, often mentioned as the most challenging type of variations and that often have a direct impact on performance [7]. It is important to map existing variations, monitor the effects and reduce the variations to be competitive [8]. This management of variations is here referred to as variation management (VM) with focus on variation reducing activities.

To identify the source of uncertainty is a first step to reduce variations but it does not automatically reveal the cause that drives the variations. In order to fully map variations it is important to identify the source and cause to find appropriate actions that reduce the variations. How well a process is studied and the information available determines the possibility to identify variations and thereby also the possibilities to reduce the variations. One important notion is that the variations, independent of source, can have different characteristics depending on the time horizon concerned. In general, the variations a company is exposed to can be classified as systematic or stochastic variations that in general represent variations of long-term patterns or short-term random patterns.

2.2 Buffer Management

Variations that remain after the application of VM can be handled by buffers to absorb variations and thereby reduce negative effects on business performance. Managers need to select appropriate buffers, positioned where needed and dimensioned to the right size to sufficiently achieve this purpose. This work is referred to as buffer management (BM). Buffer selection is mainly about choosing what type of buffer to use and for what purpose. The first feature is if the variation(s) the buffer is supposed to absorb is of systematic or stochastic character. Next the buffer selection is decided based on what type of buffer is appropriate for the specific variation. As mentioned in the introduction, buffers can be in terms of additional material, additional capacity and additional lead-time [7]. Within the technique drum-buffer-rope a set of rules for buffer positioning is proposed with buffers referred to as constraint, assembly and shipping buffers depending on their position. When the buffer selection and positioning is determined, the focus shifts to the dimensioning of the buffer size, referred to as buffer dimensioning.

2.3 Buffer Dimensioning

A buffer should hedge variations, for example unexpectedly high demand. If variations are not reduced or absorbed, they can create varying lead-times and negative effects on the delivery performance [9]. Established buffers can be used to absorb deviations from the normal requirements of materials, capacity or lead-time. The size a buffer should be depends on the amount of existing variations weighted to the costs implied to hold the buffer, in order to achieve a balance between costs, the safety provided and the risks the company is prepared to take. How extensive the safety should be is in turn determined by established performance measures. These buffer decisions are in general covered in the buffer dimensioning where the focus is on determining buffer size.

3 Service Performance Management and Buffers

Competitiveness rests on the capability of rendering service to the customers. A major challenge for competitive service performance is to reduce variations and to absorb variations through appropriate buffers. VM and BM can therefore be regarded as fundamental parts for service performance management, with the aim to meet customer needs by high service performance. In Fig. 1, it is illustrated that the subprocesses of the service performance management is influenced by three main aspects: input data, decision maker and process logic. Buffer dimensioning, as a part of BM, is the focus of attention in this research and how the main aspects can influence the decision-making process of buffer dimensioning is emphasized below.

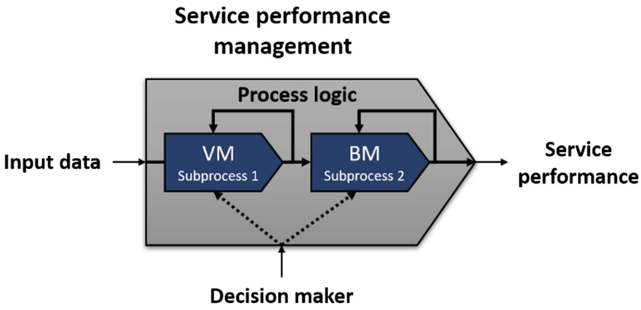

Fig. 1. Service performance management process

3.1 Input Data

Buffer dimensioning varies depending on the amount and type of available data, methods and system support. Valuable input data are for example the remaining variations after application of VM. In this research the input data is differentiated in term of quantitative or qualitative data. Input data that are measured and included in the dimensioning process are regarded as quantitative while parts that are hard to measure or simply not measured, but still considered in the dimensioning process, are referred to as qualitative input data. The amount and type of input data may be used in dimensioning but can also affect the methods used, and two main categories of methods can be identified. The first category is here referred to as assessment methods that relates to more or less intuitive and experience-based ways to determine buffer size without formally performed calculations. It can be regarded as informal methods for decision making, e.g. deciding that a buffer should be of certain size based on what has been required previously (by experience), what feels appropriate (intuition or gut feeling) or as a proportion of demand or other appropriate measures. The last example implies that simple calculations are done but as the proportion variable is to a large extent estimated this method is considered as an assessment method. The second category is referred to as computational methods and regards more formal ways to calculate the buffer size by considering statistical distributions of prevailing variations. It can for example be to calculate the buffer size based on desired service level or as a trade-off between carrying costs and shortage costs. These types of methods have been extensively researched for material buffers but are not as established for capacity and lead-time buffers.

3.2 Decision Maker

Two categories of buffer dimensioning methods were identified above, one referred to as assessment methods, relying mainly on experience, and the other referred to as computational methods, based on more formal calculations. For a decision maker the decisions can also be either more based on experience or relying on the method applied. The latter is here referred to as rational decision maker, implying that decisions are systematically decided based on facts. A rational decision maker often employs a series of analytical steps to review input data and possible outcomes before proceeding with a decision. If subjective judgement and assessment are involved it is difficult to apply fully rational reasoning. For this matter, when a decision maker instead relies on experience in the decisions it is here referred to as an intuitive decision maker meaning that information processing can be regarded as non-sequential and based on previous experiences, emotions or implicit knowledge. This infers that the decision making is subject to influence by the decision makers experiences beyond common sense, sometimes even based on an intrinsic feeling that can be referred to as gut feeling, instinct or inner sense. This type of decision maker can thereby receive input or ideas to subjectively use in the decision making without always knowing exactly where the input came from.

3.3 Process Logic

The discussion has so far focused on different aspects affecting the decisions and not the process of buffer dimensioning as such. Decision making regarding buffer dimensioning can be based on expected future requirements and feedback of the actual state of buffers. Two main process logics can therefore be identified: conventional and adaptive process logic. The former represents processes where control signals are processed based on controlled variables and actions made when variables are outside control limits. An example could be to replenish a material buffer that is below its target level. An adaptive process logic on the other hand embrace an iterative approach and adjust controllers to achieve or maintain a desired level of performance when variables are unknown, uncertain and/or change. This means that the buffer dimensioning is adapted based on changing conditions, either by updating parameters or changing the dimensioning method depending on prevailing circumstances.

4 Scenarios for Buffer Dimensioning

The main aspects identified above for buffer dimensioning are input data, decision maker and process logic. In combination they influence and create different scenarios in the decision-making process for buffer dimensioning. An integrated perspective of the main aspects is presented, followed by a discussion of scenarios resulting from this integration.

4.1 Integrating the Buffer Dimensioning Aspects

The three aspects influencing buffer dimensioning are outlined above. Even though each aspect is interesting on its own it is in the integration of the three that defines the buffer dimensioning process and its main characteristics. The quality and type of input data and the type of buffer dimensioning method can influence how the method is utilized and how the dimensioning process is performed. A typical example for a fully rational decision-making process would be that a computational dimensioning method is used and that the decision maker applies the calculated buffer size to the manufacturing system without adaptions. The other extreme would be that an assessment method that is only based on gut feeling is utilized, representing a genuinely intuitive situation. Although, there might also be situations where the decision maker has previous experiences that a certain computational method is not providing sufficient performance and that manual modifications are applied to the calculated value. The buffer dimensioning would then be partly rational and partly intuitive. However, if required input data is not available, measured or observed for a computational method, or there is a lack of computational methods available for the buffer of interest, it is hardly possible to be fully rational. Finally the decision maker may employ adaptive control in utilizing the input or adapting the dimensioning method employed based on obtained service performance. However, if no explicit adaptation is employed the approach is referred to as being conventional.

This discussion has highlighted that input data can be quantitative or qualitative, with a decision maker that can be rational or intuitive, and with a process logic that is adaptive or conventional. In total, the combination of these aspects provides three dimensions and creates eight different scenarios in the buffer dimensioning which is illustrated in Fig. 2 as a cube.

The cuboids should not be perceived as mutually excluding but rather as representing a continuum with different characteristics. In most cases there are no clear dividing lines between fully rational or fully intuitive, but rather that one aspect is more prevalent than the other and in total there are eight main categories. The buffer dimensioning within a company could therefore be classified within the cube based on the characteristics, perhaps with varying positions in the cube for different buffers. The current situation for buffer dimensioning in relation the individual decision makers preferences or in relation to desired situation can create a match or mismatch.

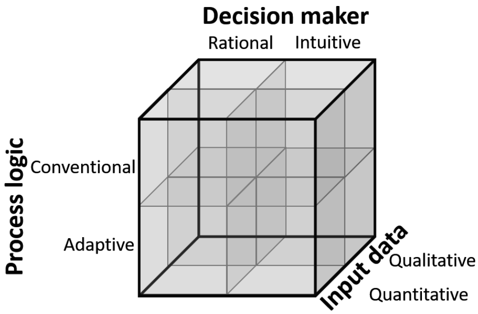

Fig. 2. An integrated perspective of buffer dimensioning aspects

4.2 Six Scenarios for Buffer Dimensioning

The cube in Fig. 2 highlights eight different cuboids that represent a unique combination of different scenarios for buffer dimensioning. However, the rational decision maker cannot rely on genuinely qualitative data and hence there are only six cuboids that represent viable buffer dimensioning strategies. Several of the identified relationships have been indicated in a research project where the buffer dimensioning process to a great extent is based on assessment methods due to a lack of decision support, especially for capacity buffers where there is a lack of established buffer dimensioning methods. For material buffers, which are well covered in the literature, the situation is slightly different with higher degrees of calculations and less of intuitive influence. One company have a fully rational approach for dimensioning of safety stock. For this company the buffer is dimensioned based on an advanced formula that only a few employees are fully knowledgeable of, which could explain why manual and more intuitive changes are not commonly employed.

5 Conclusions

A general process for service performance management has been established to be applied and provide support in the management of different types of variations in combination with buffers in terms of additional materials, capacity and lead-time to absorb the variations. The main aspects (input data, decision maker and process logic) contribute to more awareness of what constitute and affect the buffer dimensioning process, thereby creating better conditions for making appropriate changes for a mismatch between current and desired situation. Further studies can refine preconditions, challenges and opportunities for the different buffer dimensioning scenarios, outline what is needed to change to another dimensioning scenario, investigate where different types of buffers tend to be in terms of dimensioning scenarios and thereby highlight where more research is needed from a theoretical and practical perspective.

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